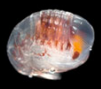


Functional differences in the eyes of three hyperiid amphipods

1

Thanks

Zahra Bagheri

Karen Osborn

Annie Jessop

Vanessa Stenvers

Julian Partridge
Bruce Robison
Rob Sherlock
Kim Reisenbichler
Freya Goetz
Western Flyer Crew
Alan Jamison

Australian Government
Australian Research Council

Smithsonian
National Museum of
Natural History

MICROSCOPY AUSTRALIA

2

Who is there?

What are they doing?

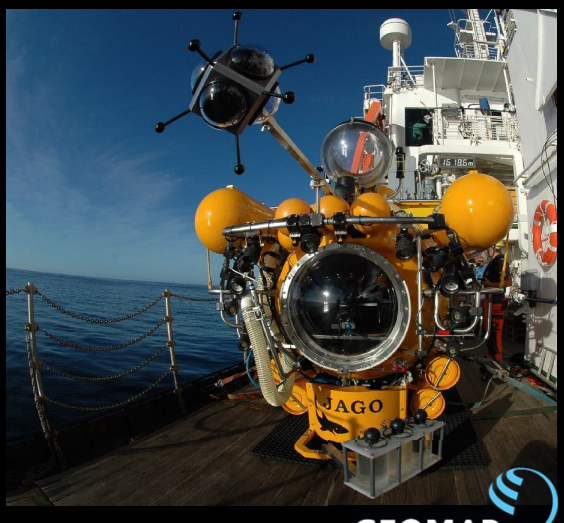
How have animals adapted?

The Midwater

Direct observations challenging

3

Underwater vehicles



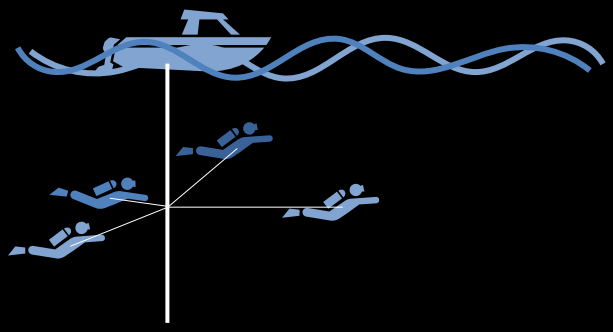
GEOMAR

RO
the

MBARI

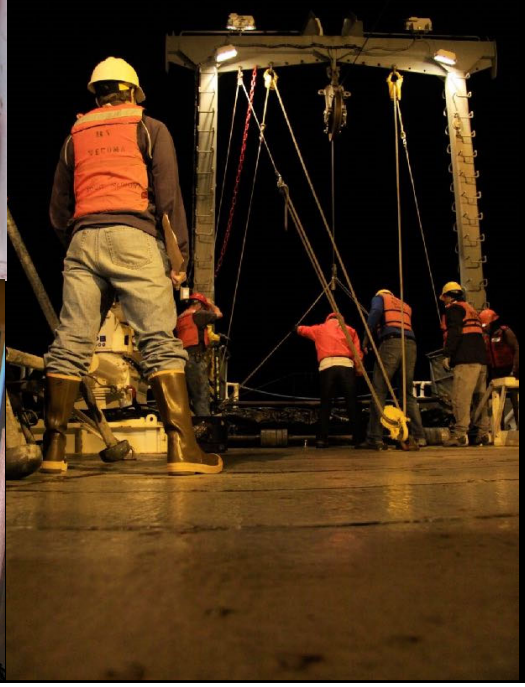
4

Blackwater diving



5

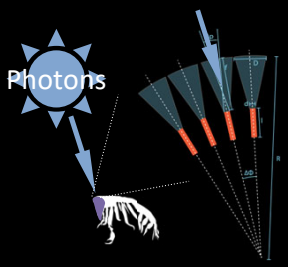
Midwater Tows



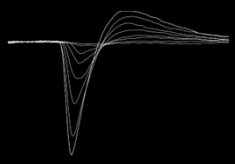
6

Integrative approach

Behavior



Morphology & Modeling



Physiology

Neuroanatomy

7

Suborder Hyperiidea

(Crustacea, Amphipoda)

- Exclusively in the midwater
- Abundant
- Hardy in the lab

8

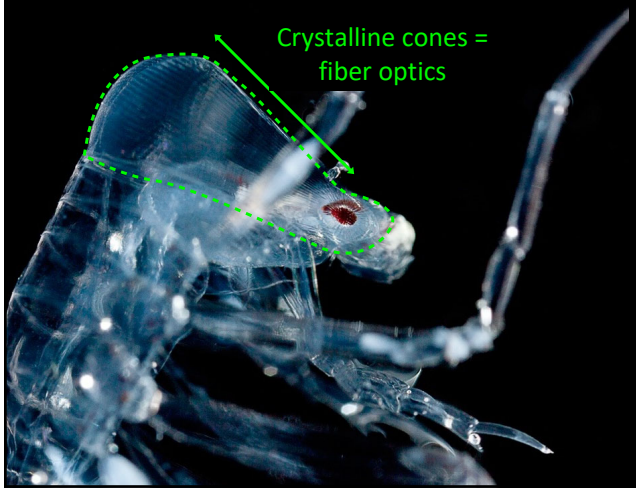
Morphological Diversity

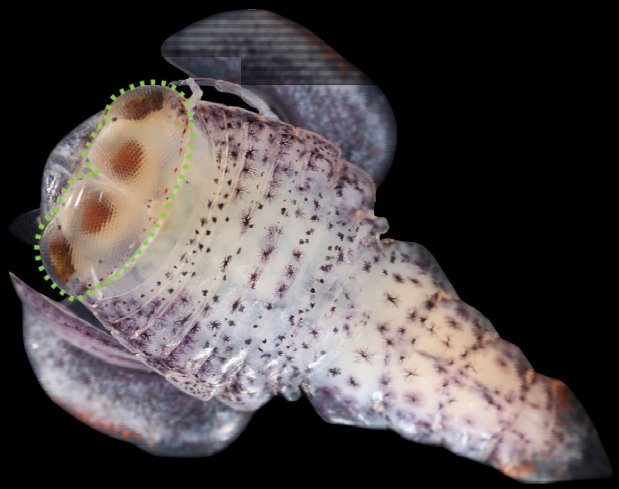
- Size
- Appendages
- Coloration
- Eyes

9

Double eyes

e.g. *Platyscelus, Phronima*





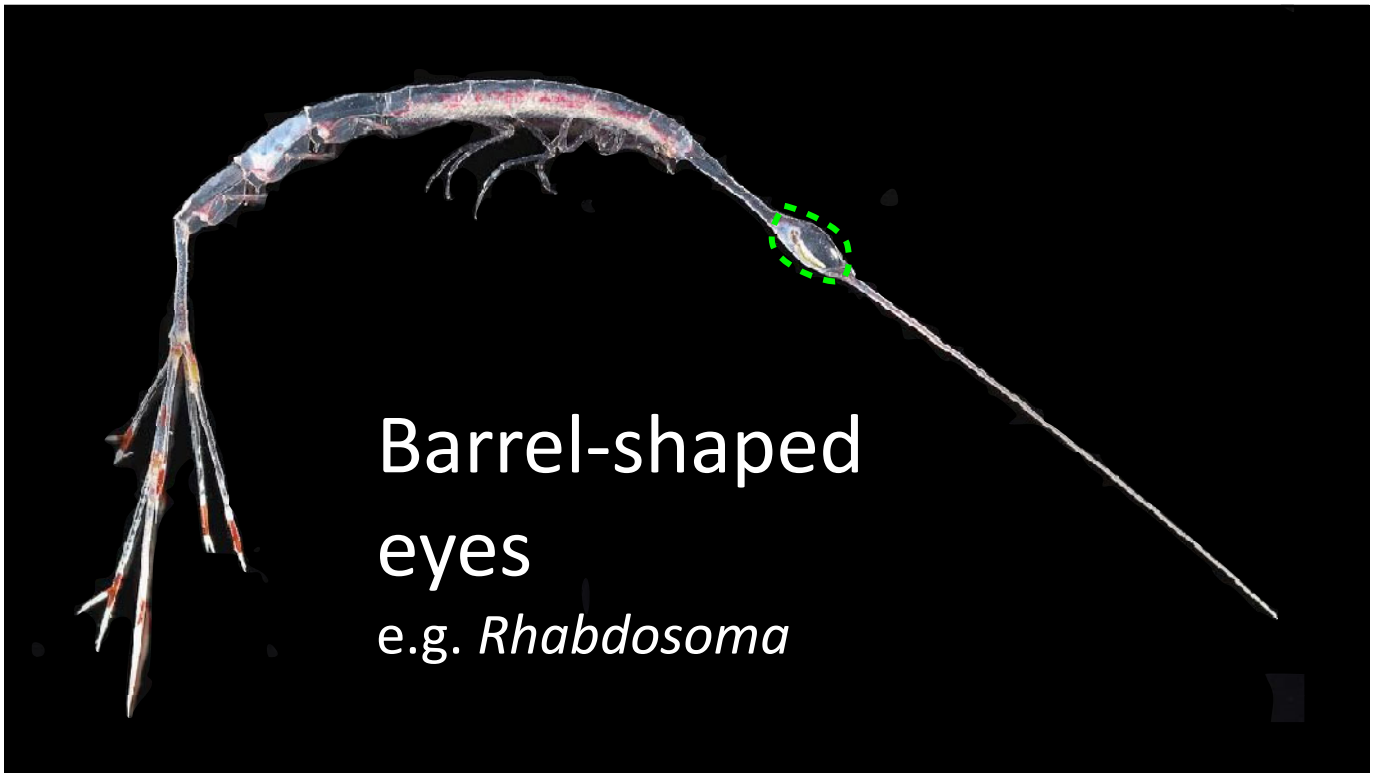
10

Mirrored eyes
e.g. *Scypholanceola*

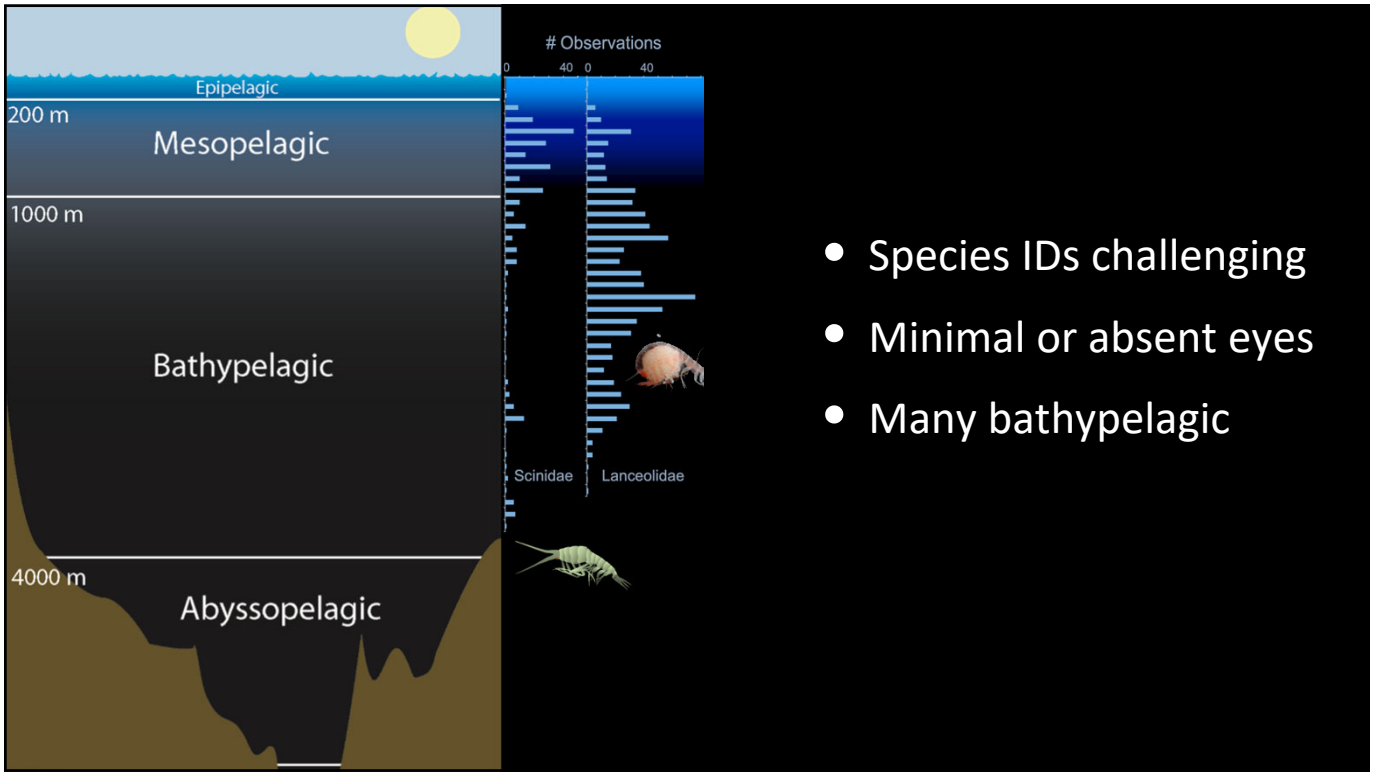
11

Distributed retinas
e.g. *Paraphronima* &
Cystisoma

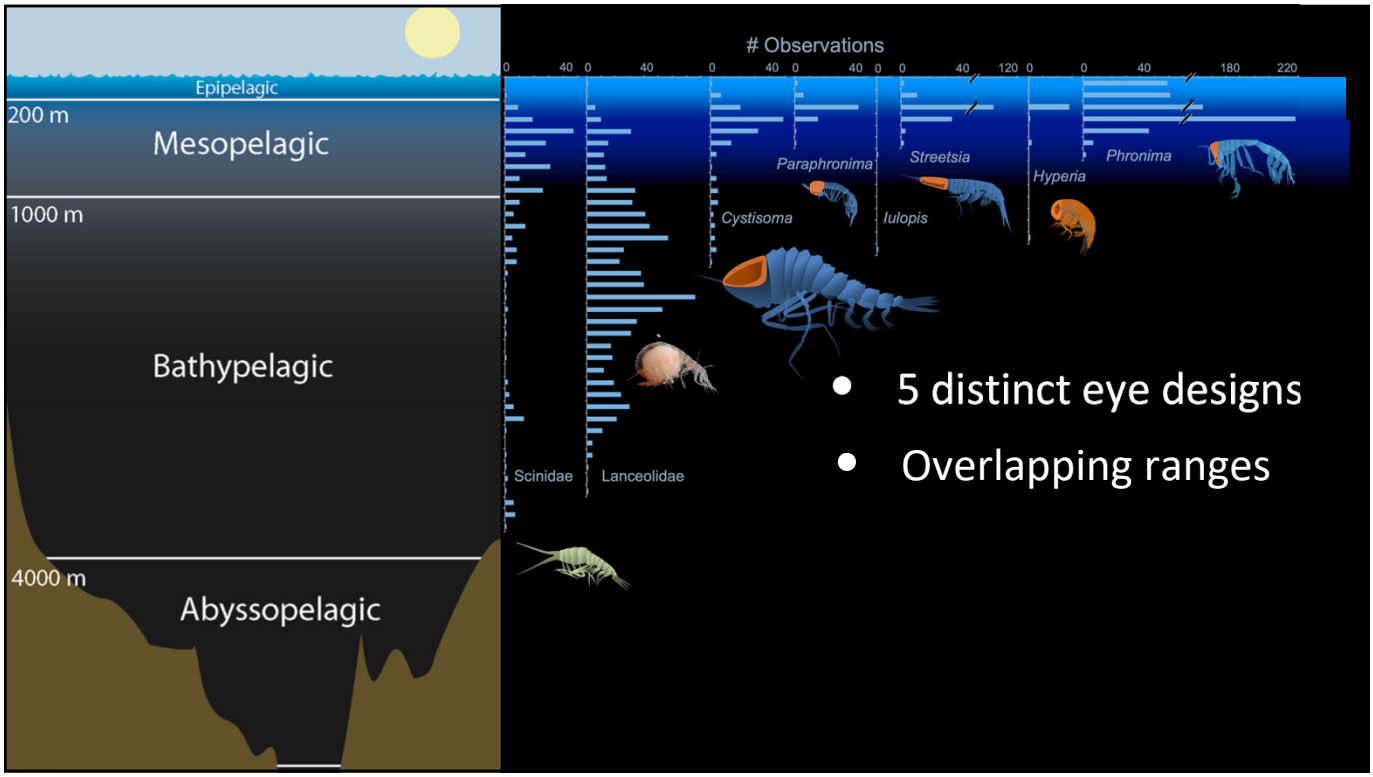
12


Barrel-shaped
eyes
e.g. *Rhabdosoma*

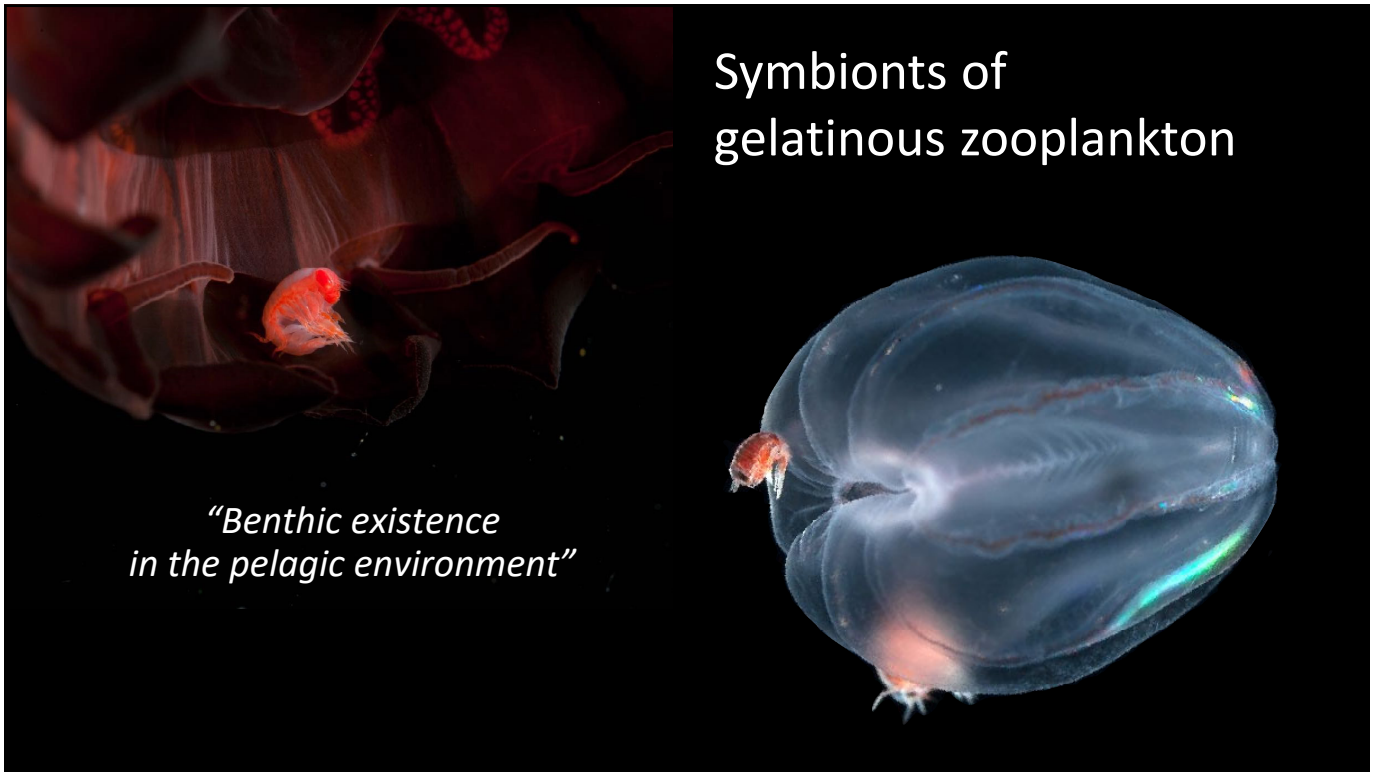
13


Epipelagic
200 m
Mesopelagic
1000 m
Bathypelagic
4000 m
Abyssopelagic
Observations
0
40
0
40
Scinidae
Lanceolidae
• Species IDs challenging
• Minimal or absent eyes
• Many bathypelagic

14


Epipelagic
200 m
Mesopelagic
1000 m
Bathypelagic
4000 m
Abyssopelagic
Observations
0 40 0 40 0 40 0 40 0 0 40 120 0 0 40 180 220
Paraphronima
Streetsia
Phronima
Hyperia
Cystisoma
Iulopis
Scinidae
Lanceolidae
• 5 distinct eye designs
• Overlapping ranges

15


Symbionts of
gelatinous zooplankton
*"Benthic existence
in the pelagic environment"*

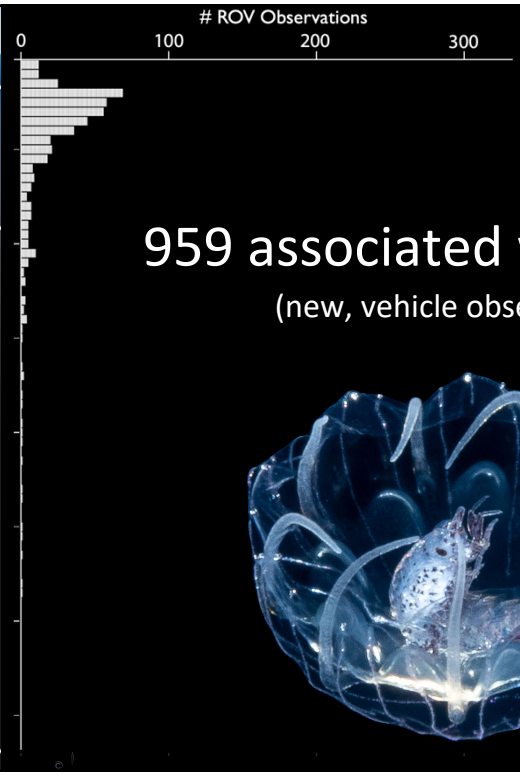
16

Hyperiid observations

Historical = 610
(literature)

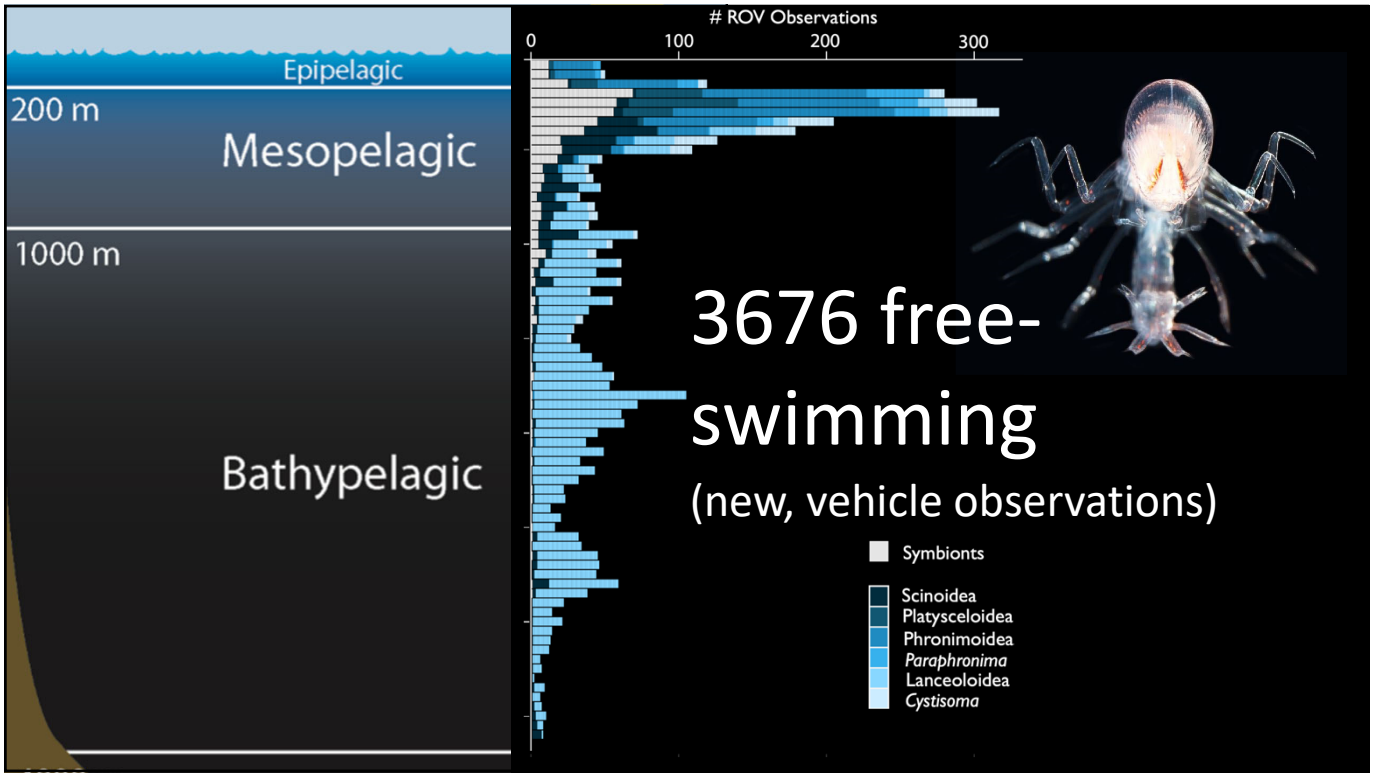
New = 4635
(Underwater vehicles / BW SCUBA)

17

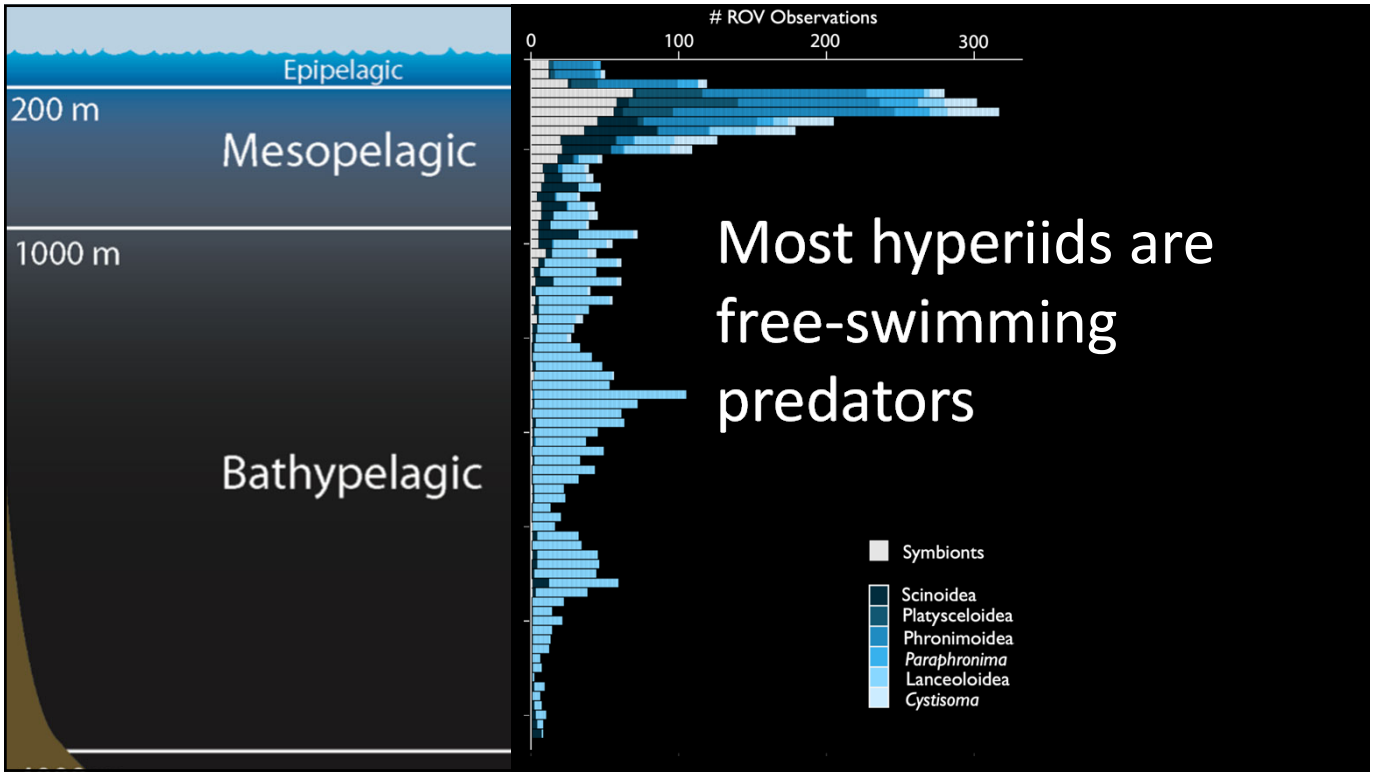


959 associated with a host
(new, vehicle observations)

18


Epipelagic
200 m
Mesopelagic
1000 m
Bathypelagic
ROV Observations
0
100
200
300
3676 free-swimming
(new, vehicle observations)
Symbionts
Scinoidea
Platysceloidea
Phronimoidea
Paraphronima
Lanceoloidea
Cystisoma

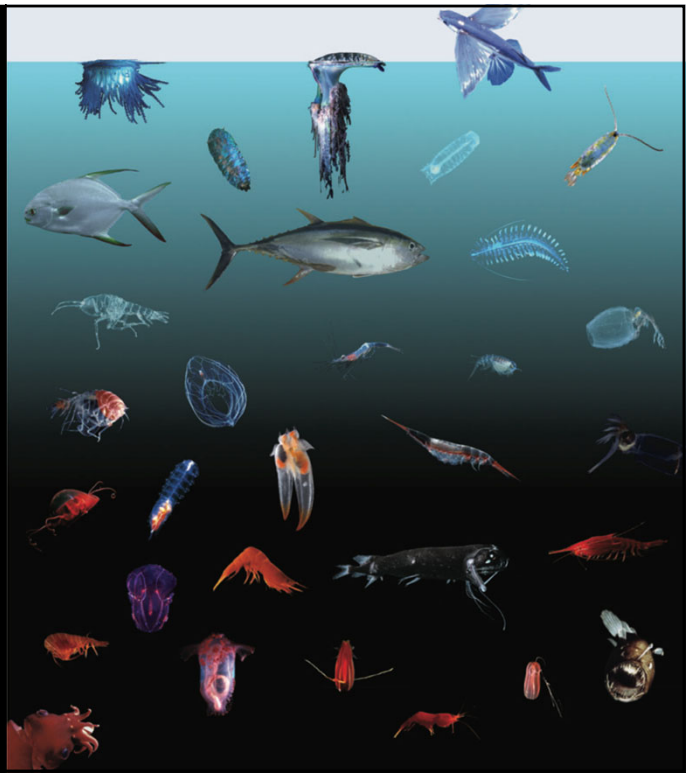
19


Epipelagic
200 m
Mesopelagic
1000 m
Bathypelagic
ROV Observations
0
100
200
300
Most hyperiids are free-swimming predators
Symbionts
Scinoidea
Platysceloidea
Phronimoidea
Paraphronima
Lanceoloidea
Cystisoma

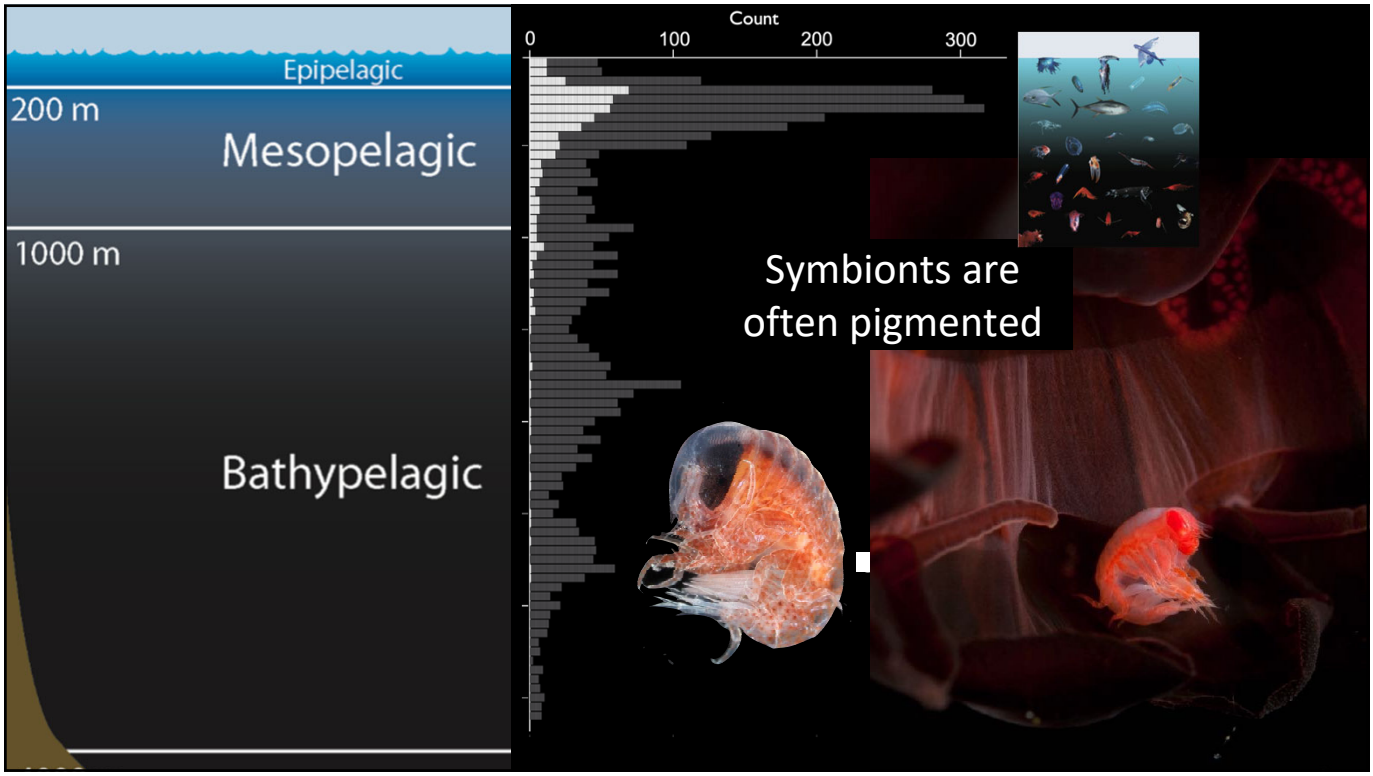
20

Camouflage patterns by depth

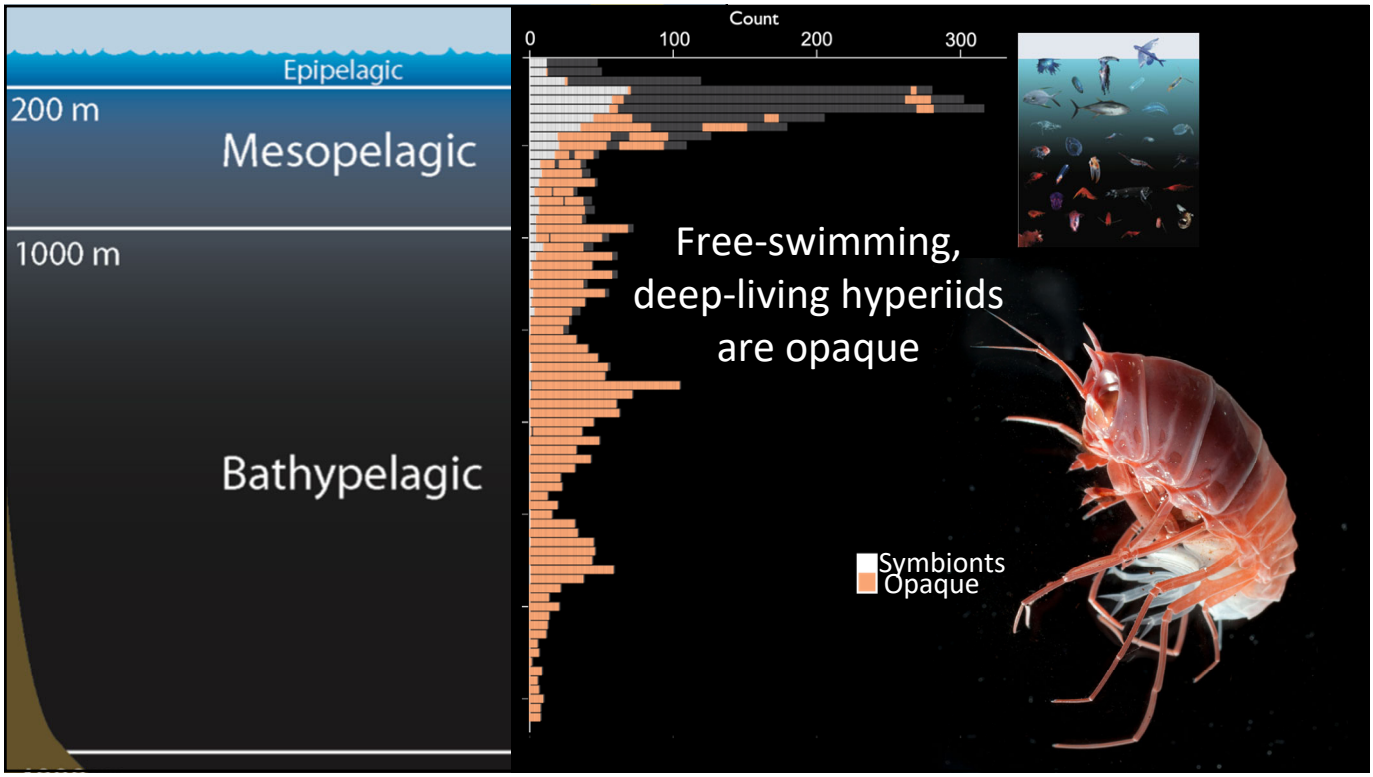
Johnsen, 2014



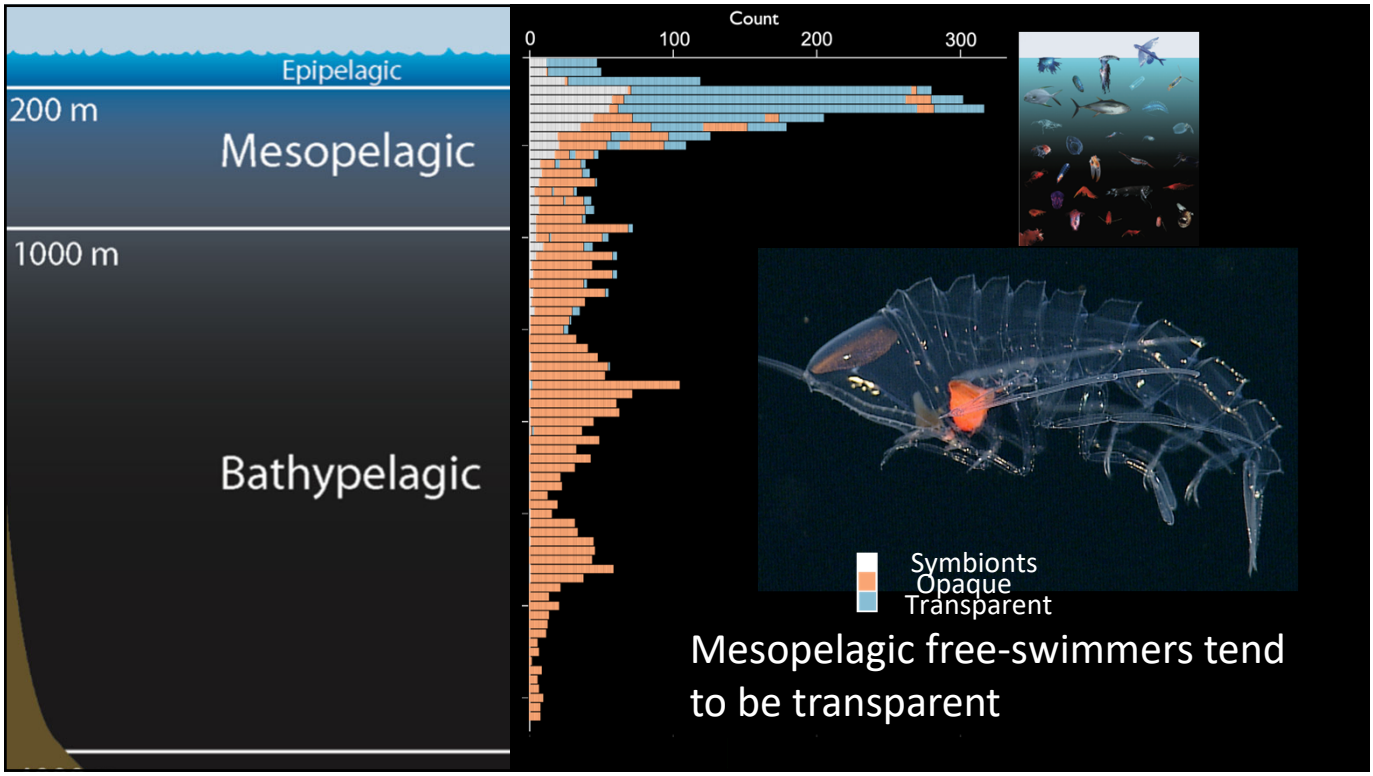
21



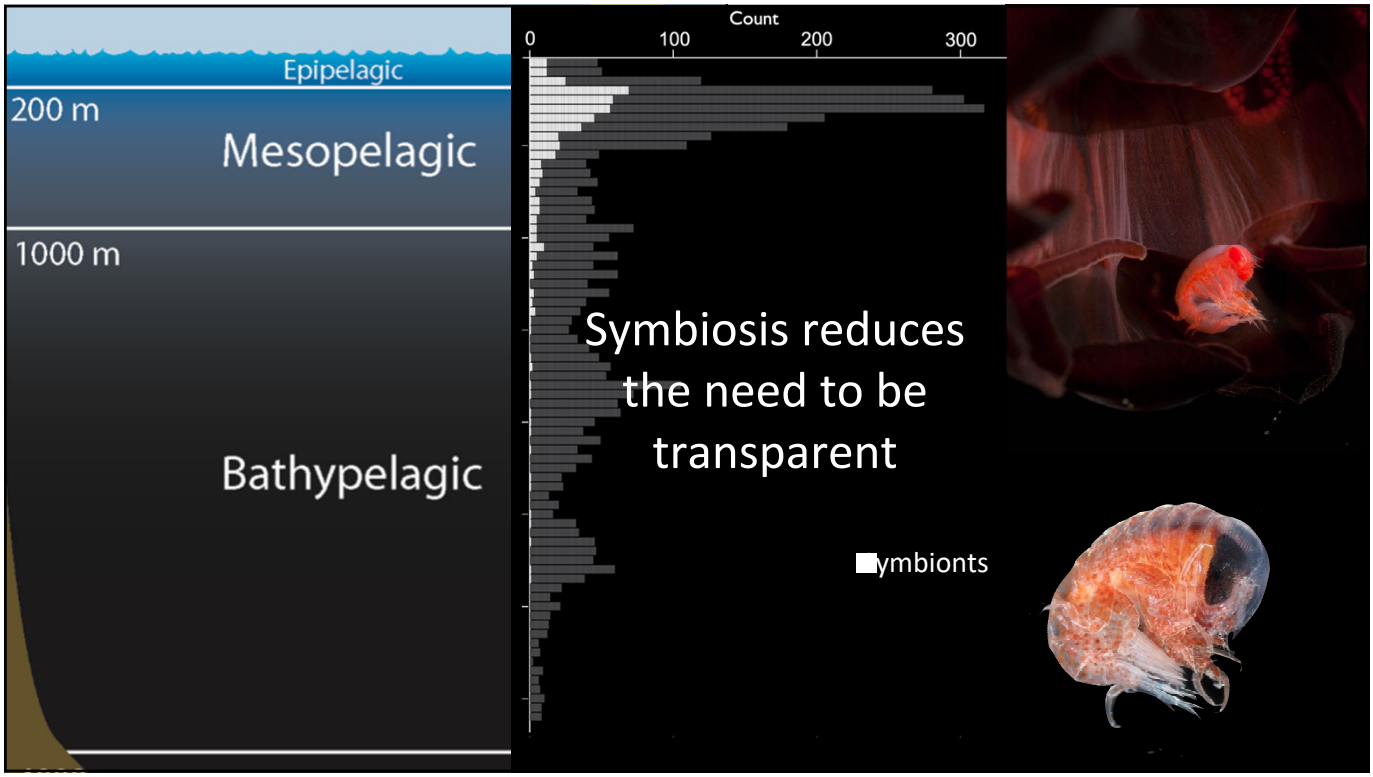
22


Epipelagic
200 m
Mesopelagic
1000 m
Bathypelagic
Count
0
100
200
300
Free-swimming, deep-living hyperiids are opaque
Symbionts
Opaque

23


Epipelagic
200 m
Mesopelagic
1000 m
Bathypelagic
Count
0
100
200
300
Symbionts
Opaque
Transparent
Mesopelagic free-swimmers tend to be transparent

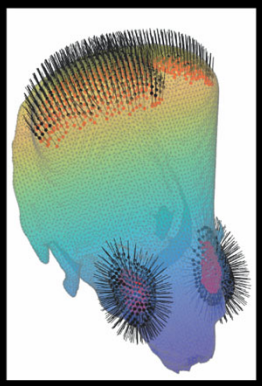
24



25

What does a free-swimming, predatory lifestyle mean for vision?

- Need faster vision
  - Need to hide retinas
    - Need large field of view or…ability to control viewing direction



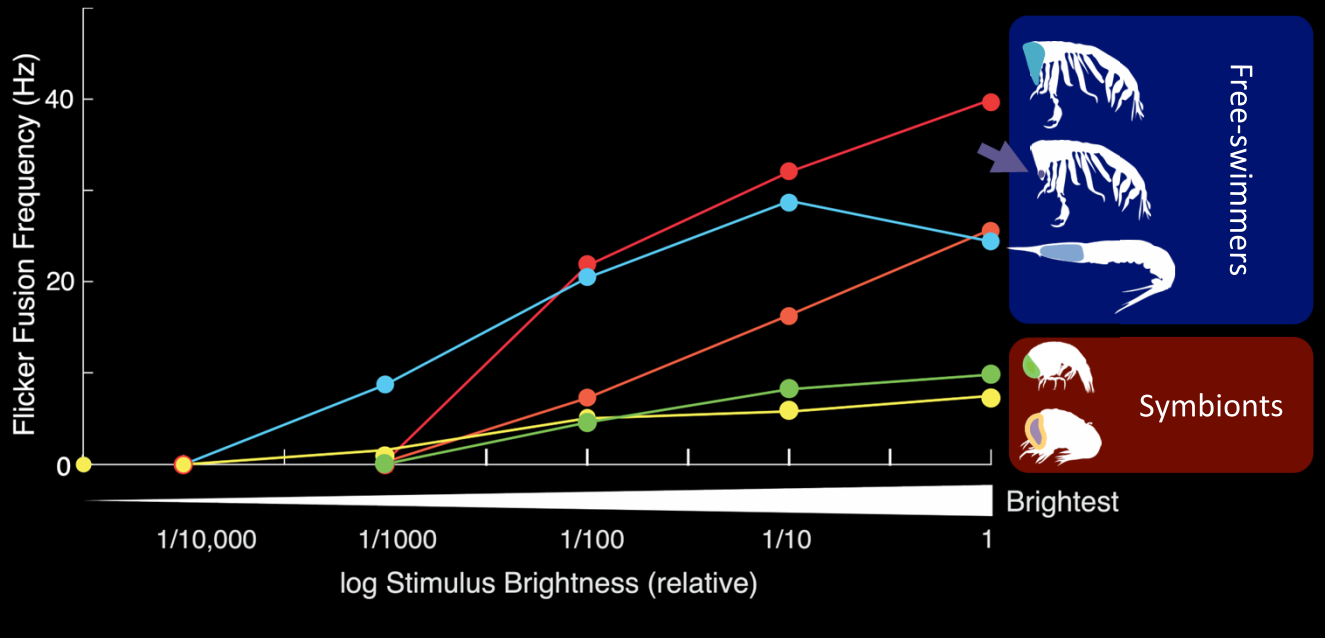
26

What does being a free-swimming, predator mean for their vision?

- Need faster vision

27

Free-swimmers have 2-3x faster FFF



28

We have learned….

- Most hyperiids are actually free-swimming predators, not symbionts

29

We have learned….

- Most hyperiids are actually free-swimming predators, not symbionts
- Free-swimming is associated with faster eyes and transparency

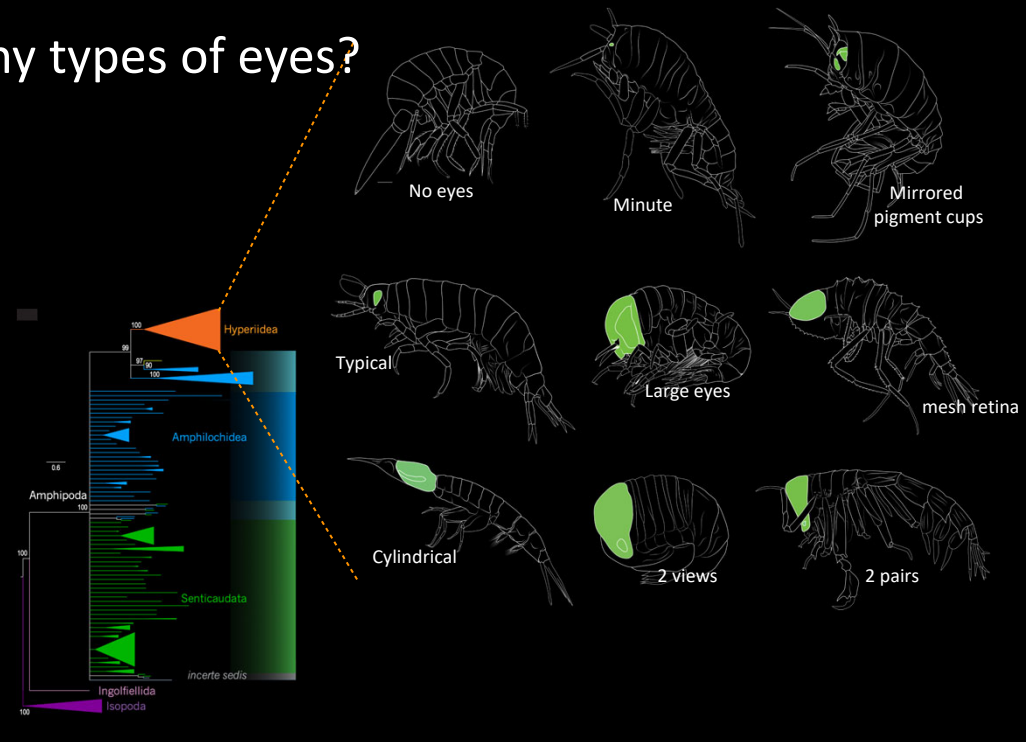
30

We have learned….

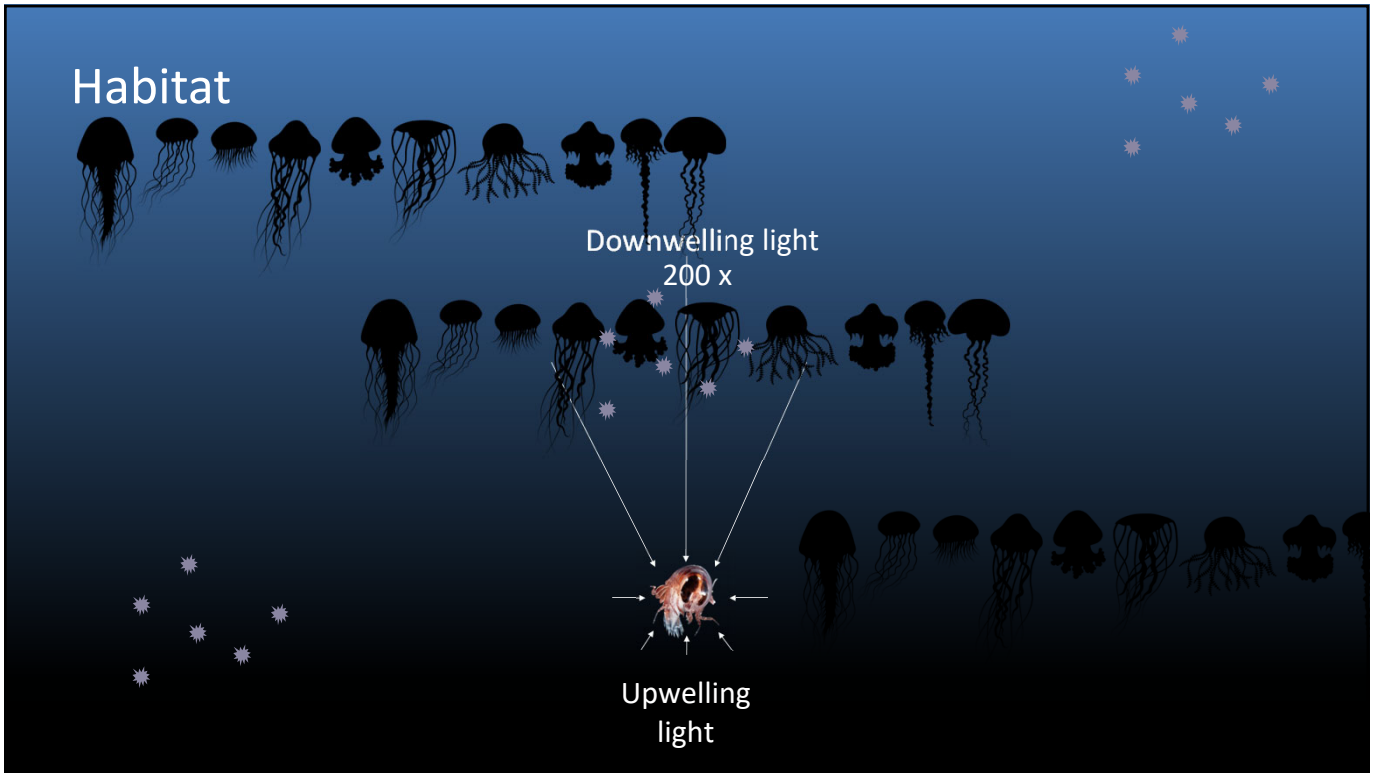
- Most hyperiids are actually free-swimming predators, not symbionts
- Free-swimming is associated with faster eyes and transparency
- Symbiosis reduces the need to be transparent

31

Why so many types of eyes?



32


Habitat
Downwelling light
200 x
Upwelling
light

33

How to remove your own silhouette 1
Countershading
• Bright from below
• Dark from above
• Silvery from the side

34

How to remove your own silhouette 2

Countershading

When there is no more light coming from below, you have to produce your own down-welling daylight:

- same colour
- same intensity
- same angle

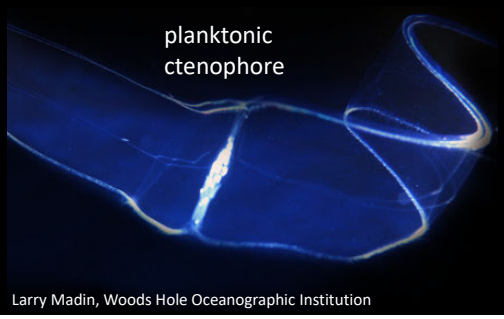
35

How to remove your own silhouette 3

Transparency in mid-water animals

Amphipod

Sea butterfly



planktonic ctenophore

Amphipod

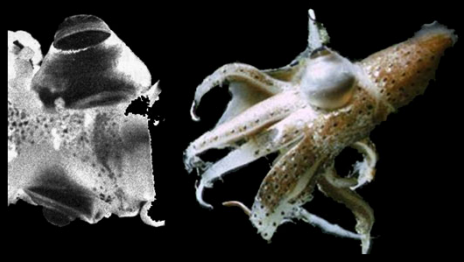
Larry Madin, Woods Hole Oceanographic Institution

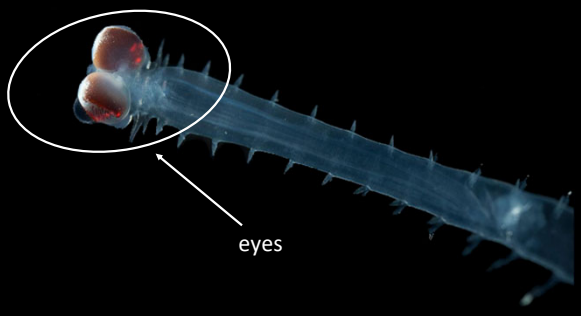
36

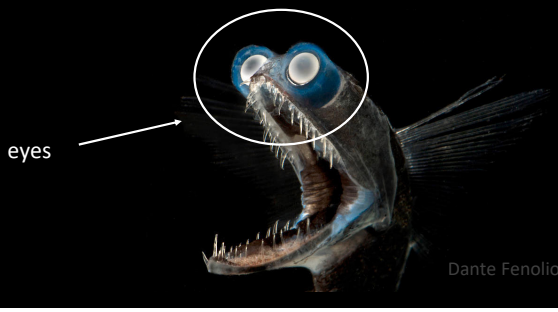
How to see somebody else's silhouette

37

Unusual visual adaptations of mesopelagic eyes



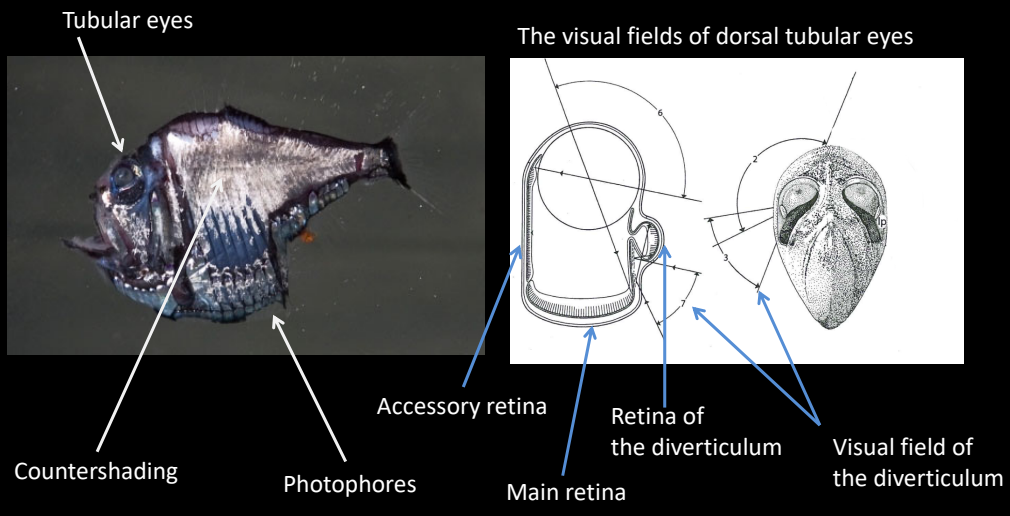




38

Optimizing sensitivity and visual field

Mesopelagic fishes often have tubular eyes that point dorsally



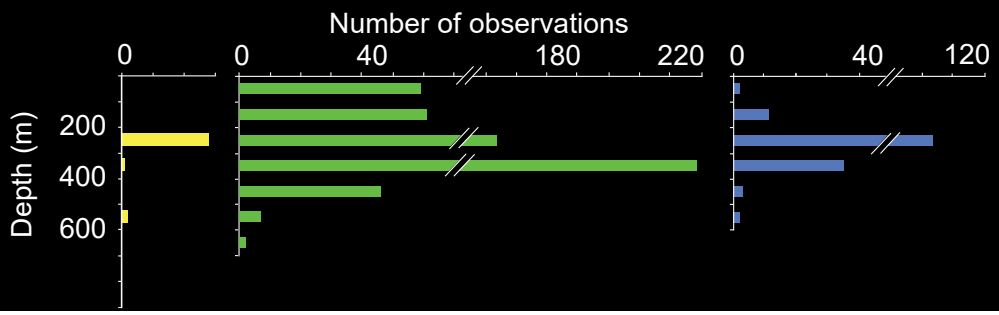
Munk 1980

39

Three hyperiids living at similar depth

Hyperia *Phronima*

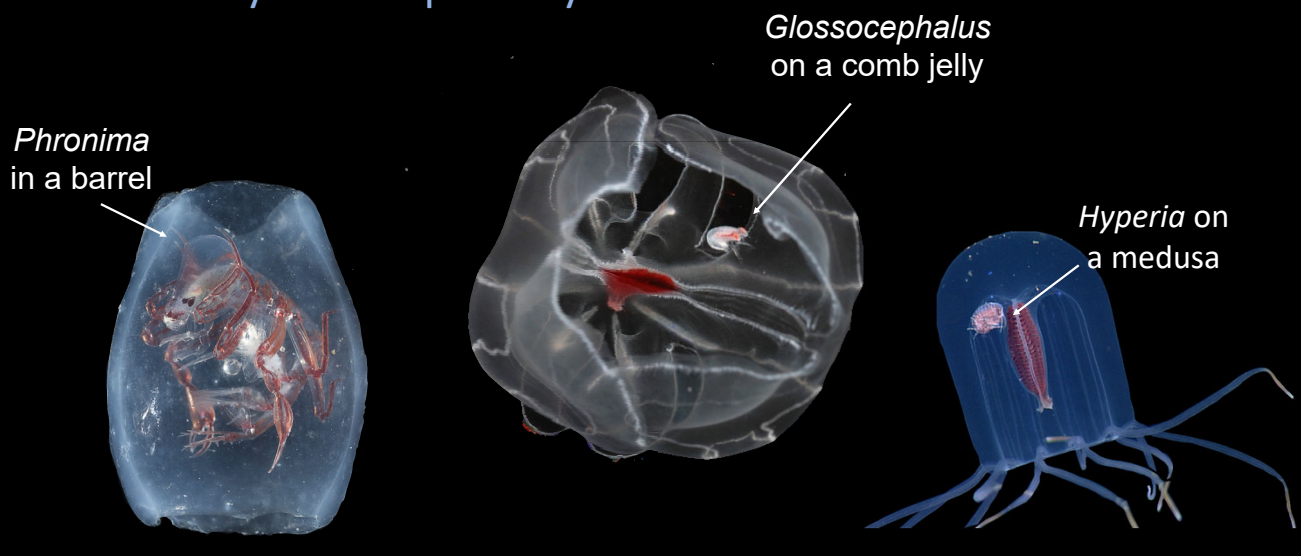
Streetsia



40

Whether or not they associate with other animals drives two key characters:

mobility & transparency



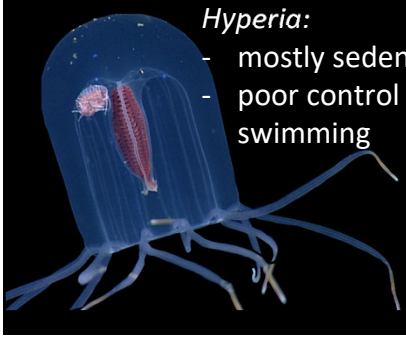
41

Mobility allows control of viewing directions

Streetsia:
- free swimming -
- fast moving

Phronima:
- free swimming
- Agile (even when in barrel)

Hyperia:
- mostly sedentary
- poor control when swimming

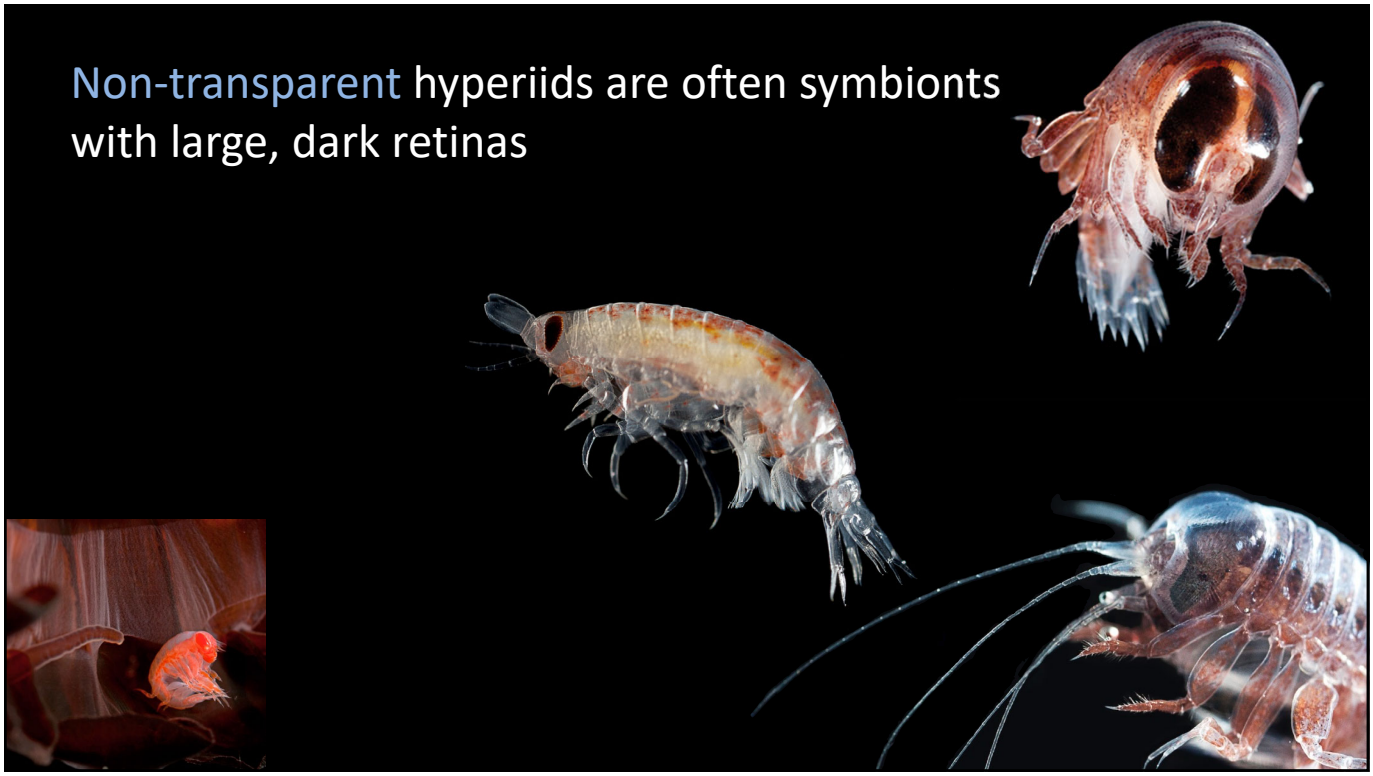


42

The retina is a major problem for transparent animals

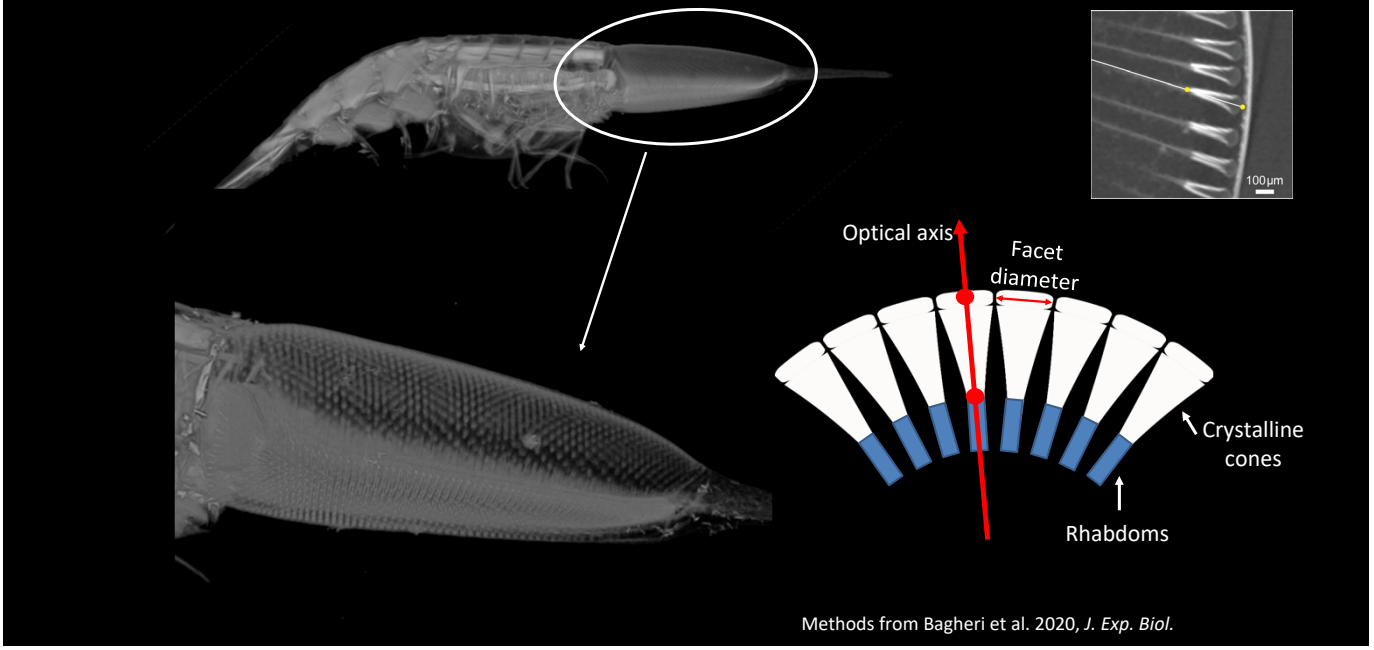
43

Non-transparent hyperiids are often symbionts with large, dark retinas



44

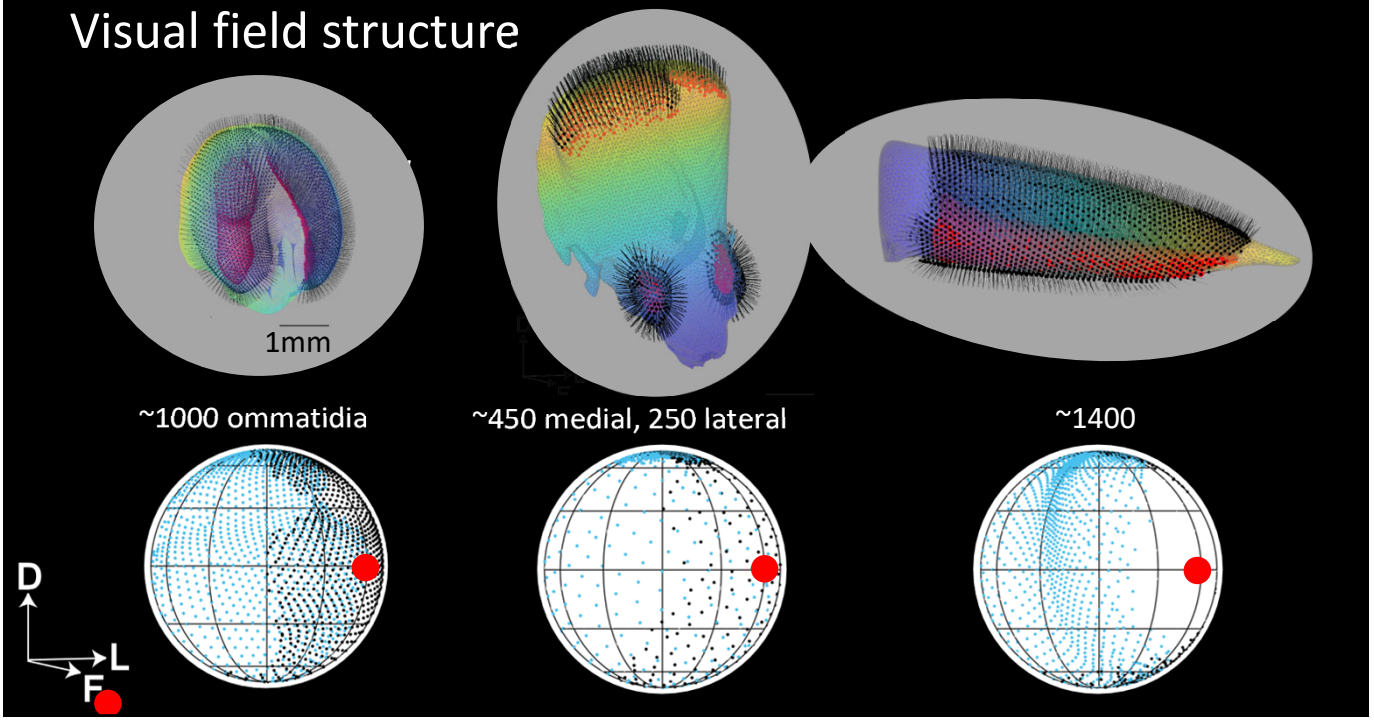
Reconstructing the visual field structure (µ-CT)



Methods from Bagheri et al. 2020, *J. Exp. Biol.*

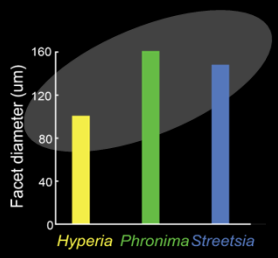
45

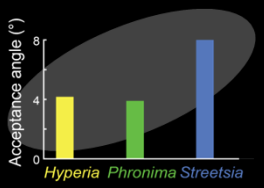
Visual field structure

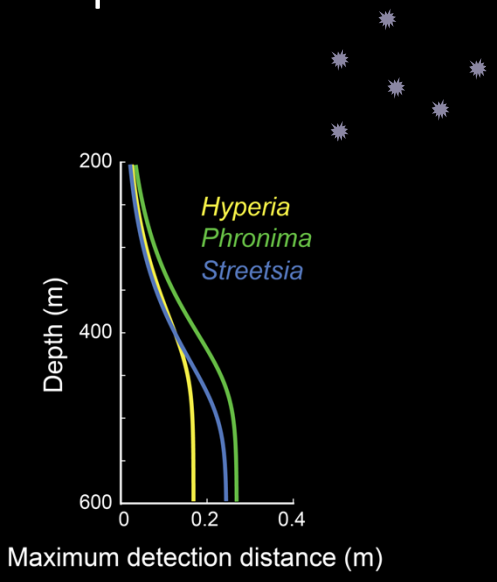


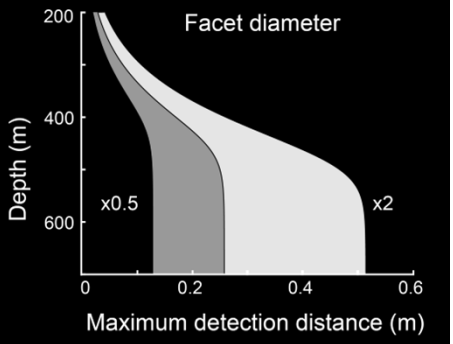
46

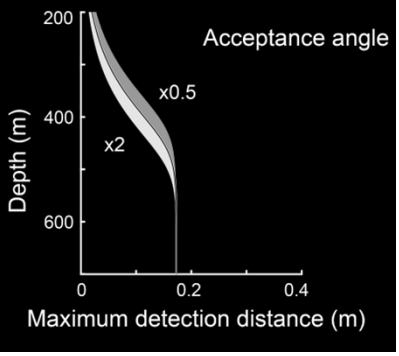
Looking upwards at point sources





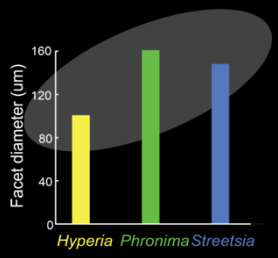


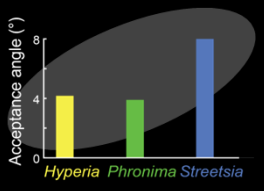


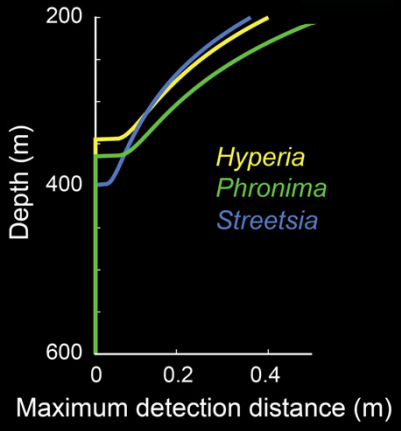


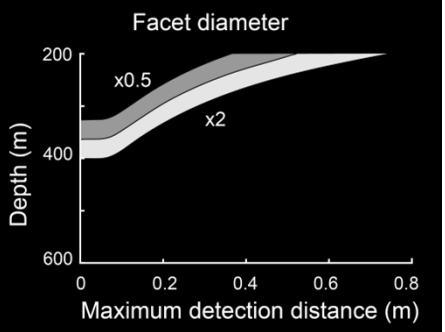
47

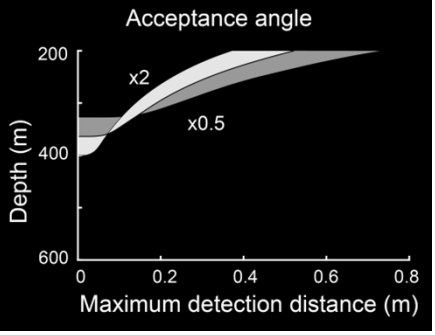
Looking upwards at dark shapes (ø 1cm)





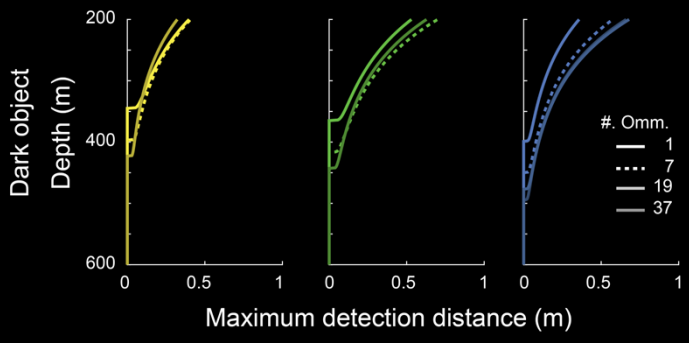


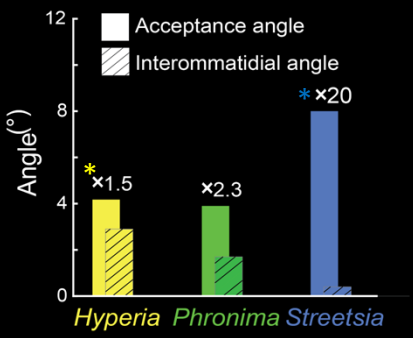




48

Spatial summation counteracts the negative effects of large acceptance angles



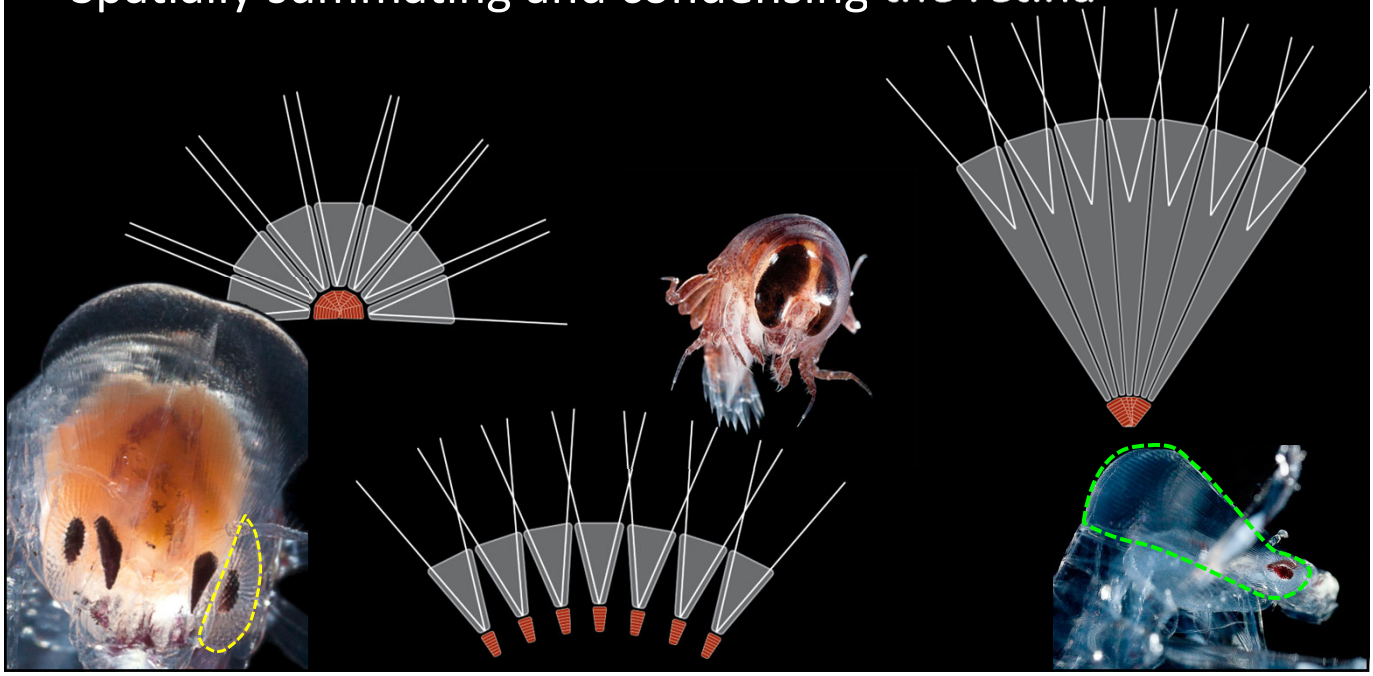


* Nilsson (1982)

* Land (1989)

49

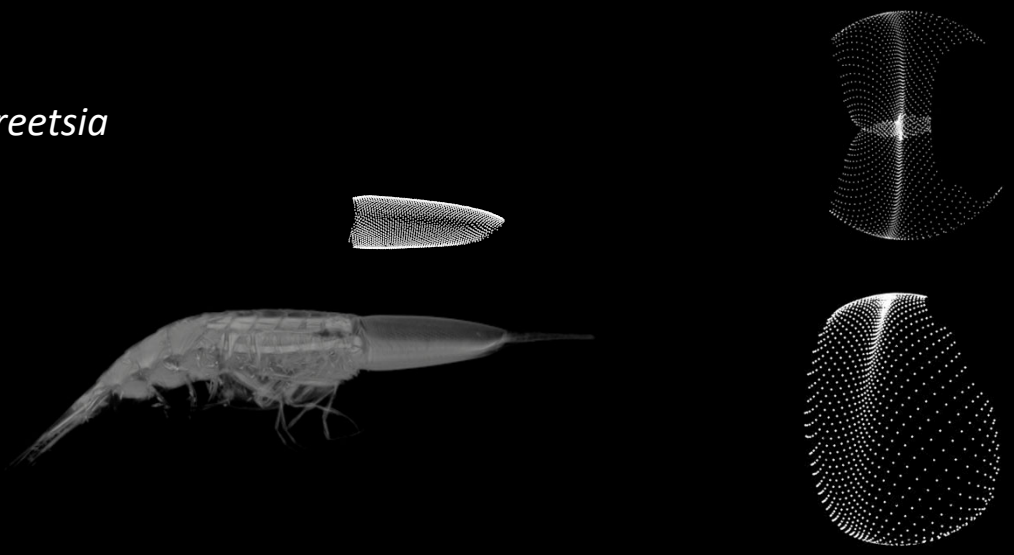
Spatially summating and condensing the retina



50

Streetsia is a *Phronima* with a cylindrical eye adapted for a streamlined swimmer

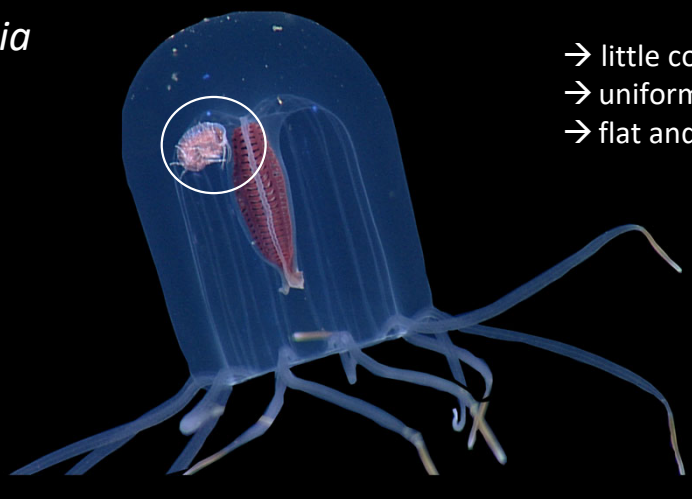
Streetsia



51

So, why all this variation? transparency and mobility

Hyperia



non-transparent & mostly sedentary

→ little control over viewing direction
→ uniform vision
→ flat and extended retina

52

So, why all this variation? transparency and mobility

Phronima

transparent & mobile, agile

→ control over viewing direction
→ narrow field of view
→ condensed retina
→ lateral eyes with large visual field

53

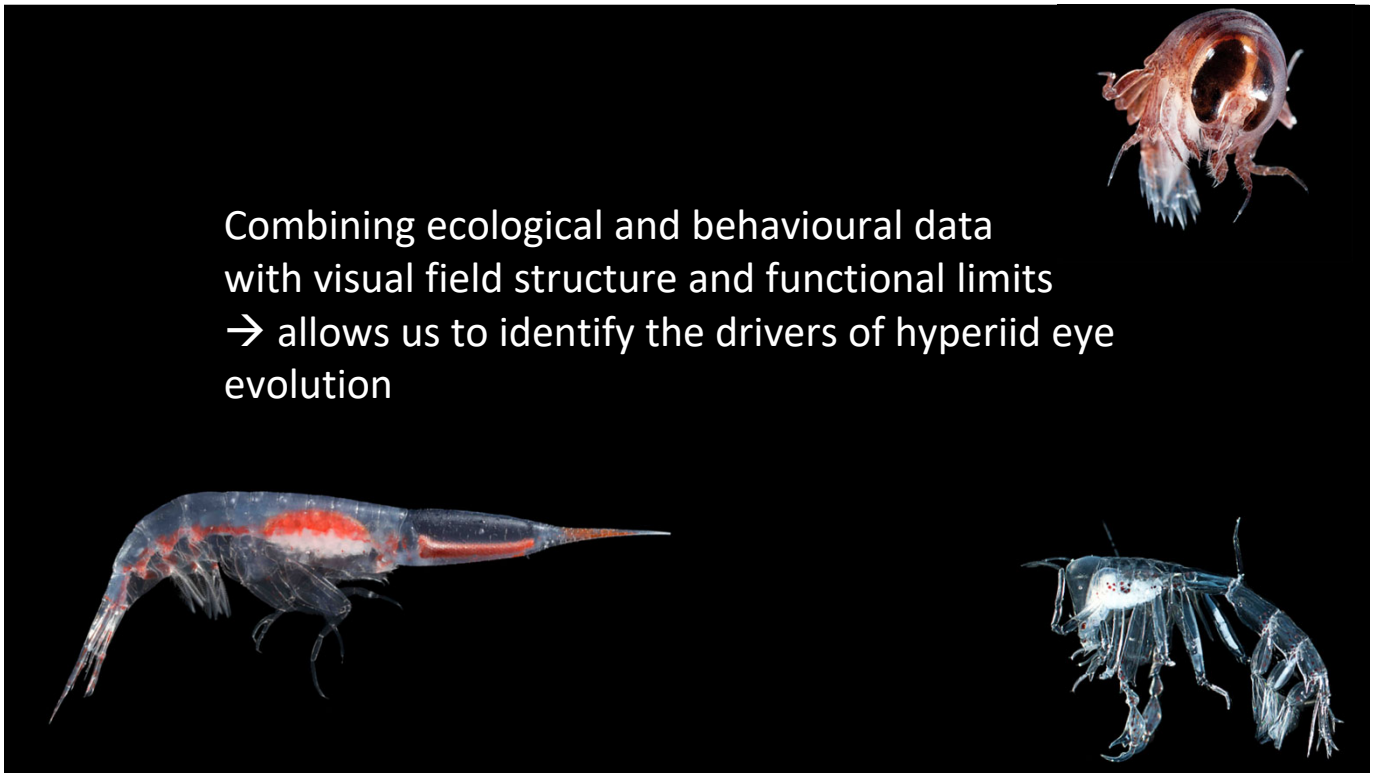
So, why all this variation? transparency and mobility

Streetsia

transparent & mobile

→ partial control over viewing direction
→ condensed retina in one dimension
→ vertical visual streak, no secondary eyes

54


Combining ecological and behavioural data
with visual field structure and functional limits
→ allows us to identify the drivers of hyperiid eye
evolution